



R.C.A. INSTITUTES. INC. *formerly* MARCONI INSTITUTE *Founded 1909*



Technical Lesson 22

FUNDAMENTALS OF RADIO RECEPTION

The transmitting station sends out electromagnetic waves. As these waves pass or cut across a receiving antenna they induce therein an electromotive force which will, if the antenna circuit is complete, cause a current to flow in the antenna. From the work you have completed on electromagnetic induction you are able to understand how a current is caused to flow in the receiving antenna system by the principle of electromagnetic induction. This current will be of the same frequency as that of the electromagnetic wave which carries it through the ether.

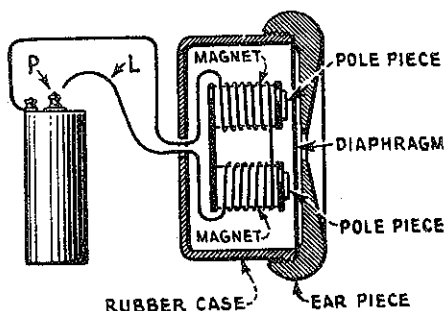


Figure 1

Now let us consider the construction and operation of the telephone receiver for a moment. Figure 1 is an open view of the receiver showing two electromagnets so supported that there is a small separation between the ends of their pole pieces and the diaphragm. There is a certain amount of residual magnetism in the iron core of these magnets so that a constant pull is exerted on the diaphragm at all times. When current flows through the magnet windings in a certain direction it strengthens the magnetic field and the thin iron diaphragm is attracted and will be pulled in closer to the pole pieces causing it to bulge in the center. If you wish to experiment and determine if the receiver coils are in perfect condition you may do so by touching the receiver terminals to a dry cell; you will hear a distinct click when touching the terminal P of the cell with the lead L and, upon removing L, you will hear a second click.

The attraction on the diaphragm is very strong when the current through the magnets is increased, and correspondingly less when the current decreases. An increase and decrease of current will cause the magnetic attraction of the diaphragm to be also increased and decreased. If the lead L is alternately placed on and removed from contact with the terminal P of the dry cell, thus making and breaking the circuit very rapidly, the diaphragm will be attracted and released as rapidly and a succession of clicks will be heard. The speed of making and breaking the connection can be increased by using a vibrator and it may be regulated so that the diaphragm will vibrate with such rapidity as to cause practically a continuous sound. When the vibrations of a diaphragm have a frequency of between 15 and about 8,000 to 10,000 vibrations each second the air waves resulting therefrom will produce

the sensation of sound. If, however, we cause the diaphragm to be attracted and released at such a rate that the resulting air vibrations would be greater than perhaps 10,000 per second no sound would be heard because the average human ear will not respond to a frequency much greater than 8,000 to 10,000. Remember there is no exact limit defined as to just where audio frequencies end and inaudible frequencies begin.

In order to include all of the possible frequencies, it might be stated that, "Frequencies above 15,000 are INAUDIBLE and frequencies between 15 and 15,000 may be AUDIBLE".

The magnet coils of the ordinary land telephone receivers have a resistance of 75 ohms and are not suited for radio reception. The receivers employed for radio reception, however, are wound with many turns of fine wire and have a resistance of from 1,200 to 3,000 ohms. A very small current in radio receivers will produce a large volume of sound.

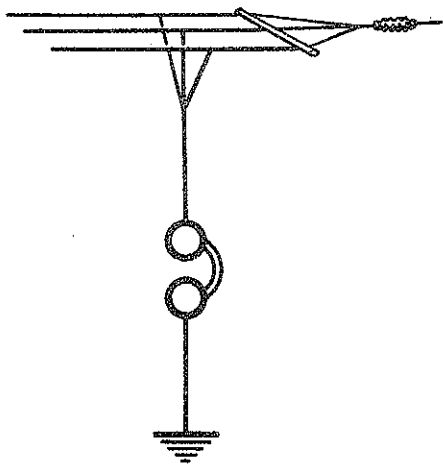


Figure 2

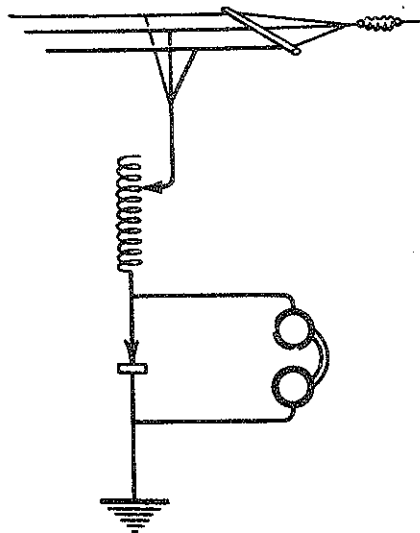


Figure 3

The current induced in the antenna by the electromagnetic wave is alternating current of very high frequency, so high in fact that if a receiver were placed in the antenna circuit as shown in Figure 2 no sound would be heard even though the current produced by the radio wave was impressed on the magnet windings of the receiver.

In the first place the high frequency alternating current is changing direction so rapidly that although the positive half cycles of current might tend to move the diaphragm in one direction and the negative half cycles tend to move it in the opposite direction, yet no vibratory motion could be possibly imparted to it because of its inertia; the diaphragm having a certain weight and mass and rigidity depending upon its thickness. The average pull or attraction on the diaphragm by the opposing positive and negative half cycles is zero.

In the second place suppose the diaphragm could follow such rapid alternations of current; we still would hear no sound because the

diaphragm would be moving at the same rate as the frequency of the radio wave and, since this frequency is above 15,000 cycles per second, it is inaudible.

Since our receiver in Figure 2 will not produce the effects of this high frequency alternating current it is evident that we must introduce some device which will allow the radio current to pass through the receiver in only one direction to make the pull on one side greater than the other. When we have accomplished this the diaphragm will then respond and vibrate at some frequency less than the radio frequencies because one half of the wave will not be exerting an equal force to act against the other half. This can be done by changing the circuit of Figure 2 to that shown in Figure 3, where a crystal detector is inserted in the antenna circuit with headphone receivers connected across the crystal. This hook up is one of the simplest and least complicated radio circuits for radio reception, but it is not efficient.

The crystal is a mineral. Galena is often used for this purpose which is silver grey or lead colored crystal, obtained in small squares with

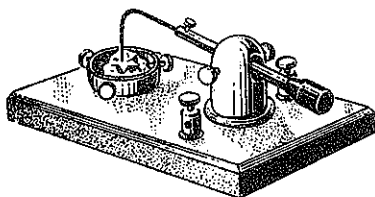


Figure 4

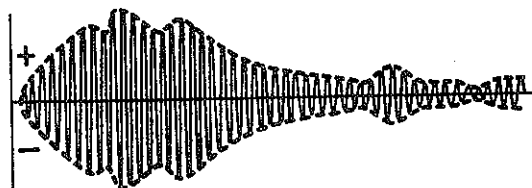


Figure 5

smooth glistening mirror like surfaces. These small pieces of galena are mounted in a metal cup in such a way that a fine piece of wire can be brought to bear on the exposed surface of the crystal. A holder for such a detector is shown in Figure 4. All places on the surface of such crystals are not as sensitive as others, and it is therefore necessary to shift the wire until a sensitive spot is located. Due to vibration the contact may be jarred loose, and also a heavy signal will sometimes cause the sensitivity of the crystal to change.

The action of this receiving set is as follows: An electromagnetic wave radiated by the transmitting antenna cuts across the receiving antenna and thereby produces an alternating current in the receiving circuit which will flow more readily through the crystal in one direction than in the opposite direction. The crystal almost eliminates half of the radio frequency wave because it presents a very high resistance to half of the wave, and a low resistance to the opposite half. (Note: The nature of crystal of certain minerals is such as to permit the passage of either the positive or the negative pulses of current, but not both the positive and negative.)

In radio telephone work the transmitter supplies the antenna with a high frequency current having constant amplitude or strength and this

current produces what is called a continuous wave or carrier wave. The sound waves directed before the microphone modify this continuous wave. Suppose, for example, a key of a piano is struck along the middle scale; the sound waves thus produced, impinge upon the diaphragm of the microphone, setting it into vibration. By means of suitable electric circuits the sound vibrations are made to change the amplitudes of the continuous or carrier wave to a form somewhat as shown in Figure 5 which is the result of superimposing audio frequency current variations upon the radio frequency carrier wave.

The alternations of the radio wave are shown by the full lines in Figure 5 while the dotted outline shows how the amplitude of the radio wave has been caused to vary in accordance with the wave produced by the piano string. This radio wave, upon striking the receiving antennae, will induce therein a current which will alternate as shown in Figure 5.

It is known that the crystal will allow one half of this wave to easily pass but will more or less effectively block the other half of the same wave. For example, we will assume that the positive half of this wave flows in the direction as shown by the full line arrow in Figure 6 and is effectively conducted through the crystal. The negative half of the radio wave current tends to flow through the crystal as shown by the dotted line arrow, but, due to the resistance of the crystal to current in this direction very little

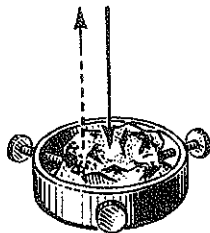


Figure 6

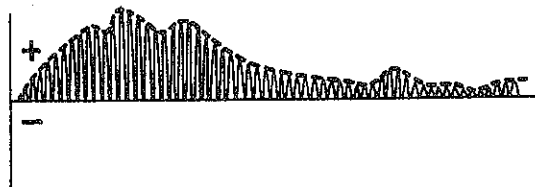


Figure 7

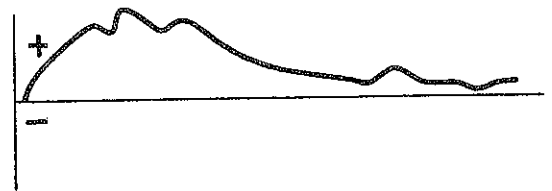


Figure 8

current passes. Therefore the negative half of the wave of Figure 5 is suppressed as shown in Figure 7.

The crystal then acts as a rectifier; it conducts electric current readily in one direction but offers great resistance to currents of opposite polarity.

The current flowing in one direction through the telephone receiver magnet coils varies the magnetic field and the diaphragm is moved corresponding to this change in field strength and this movement would appear as shown in Figure 8. The resistance of the crystal prevents, to some extent, the free flow of oscillations and tends to destroy the tuning qualities of the antenna circuit. The tuning properties of the antenna system can be improved by removing the crystal from the simple circuit of Figure 3; and connecting it in a second circuit which is called the detector circuit. This will be taken up presently.

TUNING

Radio waves from any particular transmitting station have, in general, only one wave length. The frequency of the antenna current at the receiving station will be the same as that of the transmitted radio waves and unless the antenna system is tuned to this same frequency the radio current will not be maximum in strength. This means that the receiving circuit must be so arranged that it will respond to the frequency of the radio waves coming from the transmitting circuit.

An idea of this principle of tuning may be explained by employing two tuning forks having the same pitch or frequency of vibration. When the first fork is caused to vibrate the second will vibrate also, producing a note having the same pitch as that of the first fork. The second fork was set into vibration by the sound waves produced by the first fork because it is an exact duplicate of the first fork and is, therefore subject to the same vibratory laws as the first one. Suppose we detune the second fork by attaching some wax to it, this will change its weight and it will consequently have a different fundamental vibratory frequency. If we again set the first fork into vibration, the second one will not respond as it did before because it is out of tune.

A radio receiving circuit must be so constructed that it can be tuned to the different frequencies assigned to broadcast transmitters. When a receiver is so constructed it will be possible to tune or select any desired radio wave and, at the same time, reject all other waves (within certain limits) having a different frequency. It is also possible to obtain the greatest strength from the selected wave by utilizing that which is known as coupling.

FUNDAMENTAL IDEAS OF COUPLING

Different types of coupling are employed to transfer the energy picked up by the receiving aerial to the detector. The three methods of coupling a radio receiving circuit may be described as direct or conductive, inductive, and capacitive coupling. All types of receivers make use of one or more of these fundamental ideas which will be briefly described.

Figure 9 shows the conductive form of coupling. The antenna current is conveyed directly to the detector. This circuit will produce loud signals, but it is not selective and therefore considerable interference results with its use.

The inductive coupling shown in Figure 10 utilizes the magnetic field which springs up about the primary in the antenna circuit to transfer the energy to the secondary circuit. As these magnetic lines of force, shown as dotted lines, expand from the primary circuit they cut the secondary coil and an E.M.F. is set up in the secondary which causes a current to flow in this circuit. When the primary and secondary are arranged, that is, so placed that they may be moved into a position where practically all the lines of force from the primary cut the secondary, they are said to be closely coupled. When only a compara-

tively few lines of force cut the secondary the coils are said to be loosely coupled.

The capacitive coupling method is shown in Figure 11. In this type of circuit no use is made of the magnetic field of the primary. In fact there should be no inductive coupling between coils L_1 and L_2 ; they are placed in the circuit with their axis at right angles to each other. The energy from the antenna coil is transferred to the detector, or secondary circuit L_2 , by means of the condensers C_1 and C_2 . If condensers C_1 and C_2 are large the coupling will be close

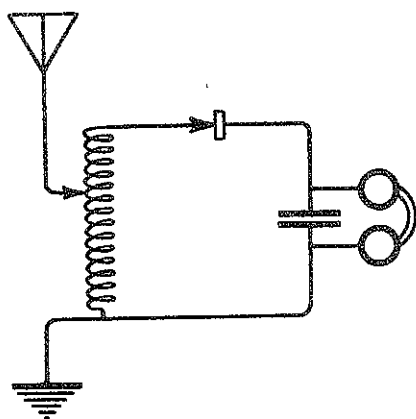


Figure 9

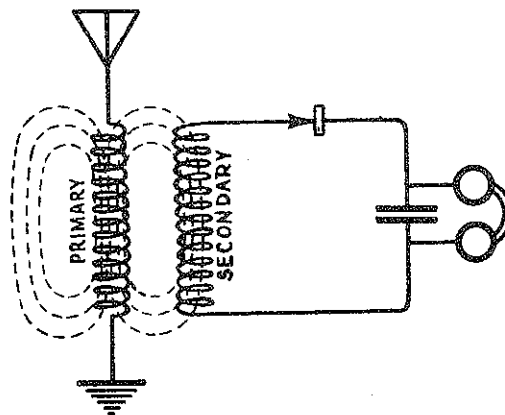


Figure 10

and the same broad tuning results would be obtained as experienced with close coupled inductive circuits. To obtain loose coupling, condensers C_1 and C_2 are either small fixed condensers of about .00004 mfd, or variable having a maximum capacity of .00004 mfd.

The tuning inductance shown in Figure 12 is made by winding a large number of turns of wire in a single layer on some insulated form. By moving the sliders S_1 and S_2 , which make contact with a bared section

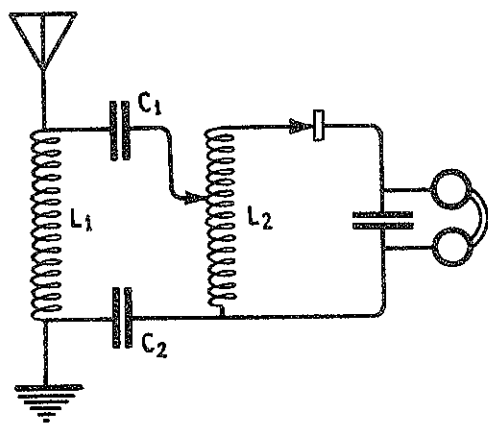


Figure 11

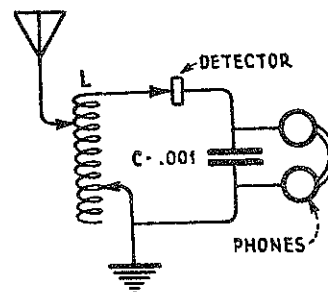
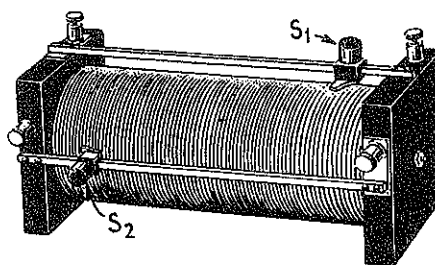


Figure 12

of the wire, the number of turns of wire to be used may be varied. In this way the antenna inductance is decreased or increased thus changing the wave length. By varying the turns on the inductance (also called tuning coil) the circuit may be tuned to the wave

length of the incoming signal. This circuit is not very selective because of the close conductive coupling effect.

THE VARIOMETER COUPLING IN THE SIMPLE CIRCUIT

Somewhat better tuning results will be obtained when employing a device called the variometer shown in Figure 13. The variometer has two sets of coils, one set fixed and the other set movable. A shaft extends through and supports the movable coil on the end of which is attached a graduated dial. The winding on these coils is made continuous by connecting the stationary coil to the movable coil through a pigtail flexible lead. This makes one continuous series winding from the beginning of the fixed coil to the end of the movable coil.

The graduated dial is generally fitted to the shaft of the movable coil in such a way that when the graduated mark 100 is up, it indicates that

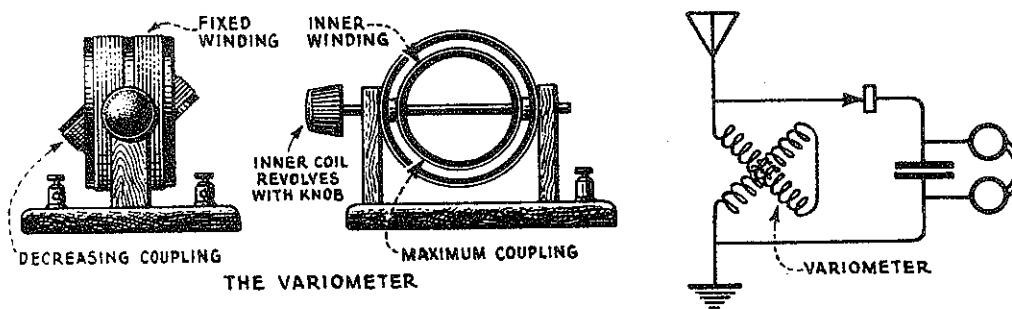


Figure 13

the movable coil is then in a position relative to the fixed coil that current flows through both coils in the same direction. The inductance is then maximum and also the wave length. When the coil dial is rotated toward zero the movable and fixed coils are then in a relative position so that current will flow through each one in opposite directions. This reduces the inductance and lowers the wave length. In this way, by moving one coil with respect to the other, fine adjustments are obtained.

The tuner of Figure 12 should be wound with about 95 turns of #18 double cotton covered wire on a tube having a diameter of 3 inches. After the winding is completed the insulation should be removed along the length of the coil to allow the sliders S_1 and S_2 to make contact with each turn but not in a manner to "short" one turn with an adjacent turn.

The variometer shown in Figure 13 should be wound as follows;- the outside or stationary coil with about 22 turns of #24 double cotton covered copper wire on a tube about 4 inches in diameter and the inside or movable coil with the same number of turns on a form just large enough to turn freely inside the fixed coil without touching. The winding on these two coils is continuous, that is, they are wound in series, because the outside winding makes connection with the movable coil by a pigtail wire which also allows this coil to be rotated through an angle of 180 degrees.

A circuit employing the variometer is similar to the double slider tuner, but instead of changing the number of turns, the field of one is made to oppose the field of the other.

THE INDUCTIVE COUPLED CIRCUIT

As stated previously the detector is usually placed in a separate circuit called the local detector circuit which is provided for by the inductively coupled arrangement.

Figure 14 is a loose coupled or inductively coupled receiver. In this receiver we have two separate windings; the one called the primary is connected directly in the antenna and made variable by means of the slider tap which can be moved along the winding cutting turns in or out as desired. The primary consists of about 70 turns of #22 double cotton covered copper wire wound on a 4 inch tube.

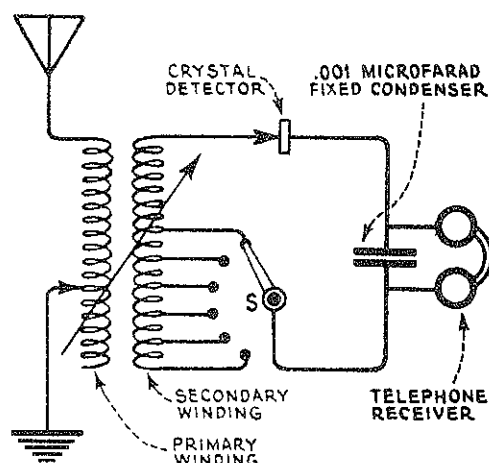


Figure 14

The secondary is entirely separated from the primary, that is, no physical connection exists between them. This winding consists of about 100 turns of #26 double cotton covered wire, wound on a 3 inch tube with taps taken off at say the 90th, 80th, 70th, 60th and 50th turns and connected to switch contacts as shown. By use of the switch "S" the number of turns in the secondary may be varied.

A form of loose coupler is shown in Figure 15 and is so arranged that the secondary may be moved in and out of the primary at will, thus increasing or decreasing the coupling between the two circuits. The purpose of the tuning arrangement in the two methods of coupling just discussed is to adjust the frequency of the primary and secondary circuits and to also provide an adjustment which will produce the proper transformer action in order that the greatest possible energy will be transferred to the secondary circuit.

When considering the circuit of Figure 12, which is a single circuit arrangement, the adjustment for frequency will depend upon the amount

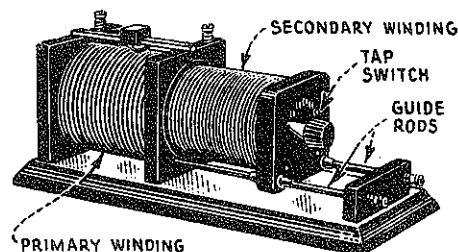


Figure 15

of inductance in the coil "L" and the capacity "C". The transformer action depends upon the ratio of the inductance L to the capacity "C" and the coupling between the circuits. In the inductively coupled, or double circuit, the same conditions hold true; the transformer action also depends upon the coupling between the two windings. (Coupling in this case refers to the relative position of the primary and secondary coils.) Figure 15 shows the two circuits loosely coupled but when the secondary winding is moved to the left into the primary winding the coupling is decreased or becomes closer. To increase the coupling the secondary coil is moved close to the primary; to decrease coupling the secondary is moved away from the primary. Loose coupling gives better selectivity than close coupling.

The scheme of coupling two radio circuits then may be regarded as a sort of filter. The antenna circuit itself will partly pick out or filter the wave desired and this filtering scheme is carried on to a much finer degree by the secondary circuit.

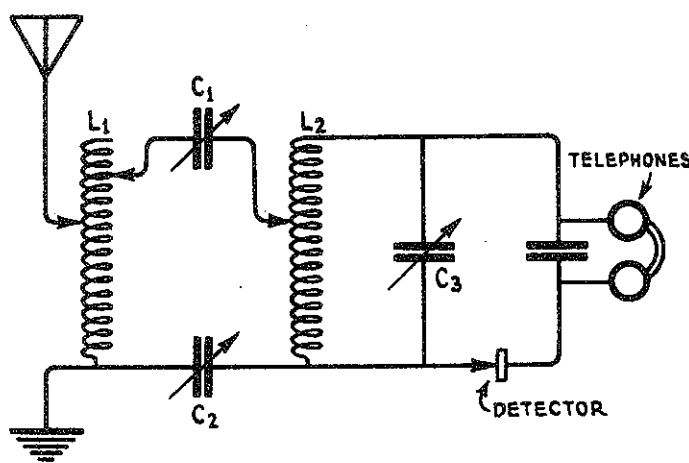


Figure 16

A circuit such as shown in Figure 12 will give loud signals but a varied assortment of waves come in at the same time, in other words, it has poor selectivity. In the double circuit however loose coupling generally gives much better selectivity but at the sacrifice of signal strength, that is, the signal heard in the telephones will be much weaker unless the circuit is constructed in a manner that will enable the energy acting on the secondary circuit to be increased to an extent that will offset the effects of loose coupling. This can be done by winding the secondary with a few more turns than the primary but care must be taken not to place an excessive number of turns on the secondary.

CAPACITIVE COUPLING

The method known as "capacitive coupling", is shown by the diagram, Figure 16. The primary and secondary coils designated by L_1 and L_2 are not in direct inductive relation. They are said to be electrostatically coupled through the condensers C_1 and C_2 . In practice the condensers C_1 and C_2 are mounted on a single shaft and then capacity varied simultaneously by a single control knob.

It is claimed that since a fixed potential exists across coil L , the energy transferred to the secondary circuit varies as the capacity of condensers C_1 and C_2 . The greater the coupling the greater will be the transfer of energy from the antenna to the detector circuit hence the coupling between the circuits varies as the capacity of the coupling condensers.

INDUCTIVE COUPLING WITH TUNED SECONDARY

Figure 17 represents a double circuit receiver in which the coupling is accomplished by varying the distance between the primary and secondary coils. This circuit can be very closely coupled and made selective by inserting a variable condenser across the secondary coil, as shown. When the frequency of the primary and secondary are tuned exactly alike by varying the inductance of the primary and the capacity of the secondary the current flowing to the telephone receivers will be maximum, thus giving a loud signal.

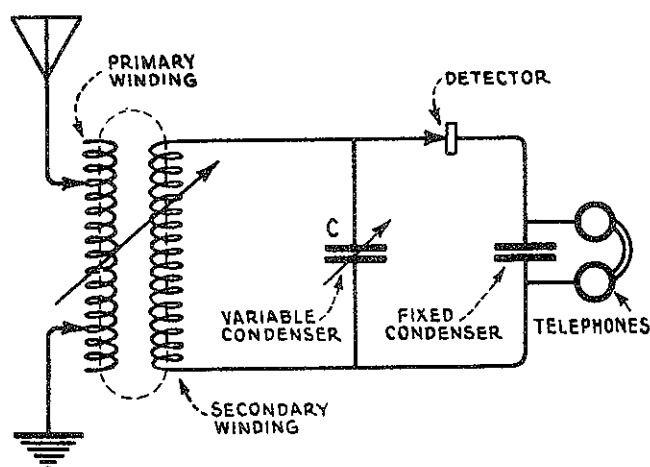


Figure 17

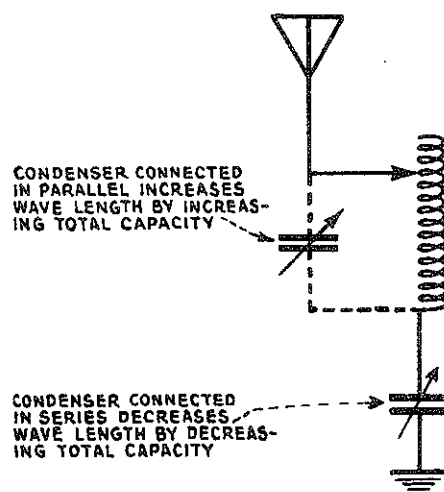


Figure 18

ANTENNA ADJUSTMENT FOR LONG AND SHORT WAVES

When it is desired to receive wave lengths shorter than the wave length to which the antenna system (the antenna and primary inductance coil) will respond it is necessary to employ a variable series condenser. This condenser is usually placed in the circuit with the rotor plates connected to the ground side. When the capacity of the condenser is decreased the wave length is decreased. This arrangement is shown in Figure 18 and is employed when a long antenna is used.

A variable condenser connected in parallel to the tuning coil of the antenna system will accomplish this result. This is shown by the dotted line in Figure 18. The series condenser must then be removed.

The student should keep in mind the fact that the antenna is like a condenser and the antenna wires form one plate and the ground the

other plate, and the space between the aerial wires and the ground forms the dielectric. Now when an additional condenser is connected in parallel to the antenna system the capacity of the antenna is increased; when connected in series it is reduced. The total capacity of two condensers connected in parallel is equal to the sum of their capacities, whereas the total capacity of condensers connected in series equals the product of the capacity of the first times the capacity of the second divided by the sum of the capacity of first plus the capacity of the second thus

$$\frac{C1 \times C2}{C1 + C2} = \text{Total capacity of condenser in series.}$$

or the reciprocal formula, explained in a previous lesson, should be used.

CRYSTAL DETECTORS

There are other minerals besides galena which will act as detectors and which come under the crystal classification; they are Silicon, Zincite Bornite, and Carborundum.

The vacuum tube, however, has supplanted nearly all crystals. It is extremely sensitive and possesses the property of amplifying the received signal to a much greater extent than a crystal detector.

EXAMINATION - LESSON 22

1. Of what use is the diaphragm of a telephone receiver?
2. Are vibrations which have a frequency above 15,000 cycles audible?
3. Will a high frequency current actuate the diaphragm of a telephone receiver?
4. Explain the action of a crystal when used as a detector.
5. Tell in your own words what you can about the principle of tuning and the purpose of coupling.
6. (a) What is conductive coupling? (b) Inductive coupling?
(c) Capacitive coupling?
7. How are the windings of a variometer arranged?
8. Draw a diagram of a simple inductively coupled receiver.
9. Name a few minerals that may be used as detectors.
10. Where are variable condensers used to advantage in a receiving circuit?